Relationship between morphology and resource utilization in freshwater fish of West Bengal

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INTRODUCTION

Morphometrics is the study of relationship between patterns of shape variation and its co-variation with extrinsic (e.g. geography, species etc.) and intrinsic (e.g. growth) factors (O'Higgins, 2000; Adams *et al.,* 2004). Geometric morphometrics quantify variation in the shape using Cartesian co-ordinates of anatomical landmarks (Adams *et al*., 2013). This approach helps to understand the associations between the morphology of animals and their ecology in terms of form and function (Franssen *et al.,* 2014). Trait based approaches to community ecology revealed first by Kryzhanovskii (1949), who described the ecological grouping of fishes (Frimpong and Angermeier, 2010). Consequently Root (1967) gave the 'guild' concept, describing it as "***a group of species that exploit the same class of resources in a similar way****".*

Successful classifications into functional feeding groups can be done by investigating the regional and local species pools from where detailed knowledge of diet and feeding behavior can be gained (Frimpong and Angermeier, 2010). There are numbers of local and global factors that change the fish communities in time and space. Bhat (2004) listed following local and global factors –

1) The global factors: river size, resource availability etc.
2) The local factors:
    a. Biological factors- competition, predation.
    b. Physical factors- habitat diversity, water chemistry, flow regimes, temperature, channel morphology.

Fishes being the largest group of early vertebrate received extensive morphometrics studies among animals. . In teleost fishes, the jaw system have shown that different phenotypes can converge on the same area of functional space, resulting in many-to-one mapping of morphology on function (Wainwright *et al.,* 2004; Alfaro, Bolnick and Wainwright, 2005).). If selection on function is strong and the morphological solutions are limited, then convergence is expected to occur (Herrel *et al*., 2008). Therefore, a realized niche of fish can be explored by studying species-habitat-biotic interactions. **The ecomorphological theory predicts that species with similar morphological characters of digestive tract will have similar diets and occupy same trophic guilds** (Soares *et al*., 2013). Fish is an indicator species of instream resources as they live in different flows and conditions during their whole life according to their life stage demands (Jain, 2012). Today freshwater makes up only 0.01% of world's water and experiencing biodiversity decline far greater than terrestrial ecosystems due to over-exploitation,

water pollution, flow modification, destruction and degradation of habitat and invasion by exotic species (Dudgeon *et al.,* 2006). For these reasons, more than 20% of the freshwater fish species are at risk of extinction. They are world's most threatened vertebrates after amphibians (Palavai, 2009). This trait based approach can be used to explain changes in species assemblage composition due to habitat alteration, modelling species response to environmental change, explaining species extinctions and aquatic biological assessments, predicting social value of ecosystem services such as nutrient regulation, harvestable food, recreation etc. (Frimpong and Angermeier, 2010).

Only few attempts with such approaches have been available, so far freshwater fish species are concerned. Oliveira *et al.* (2010) found considerable similarities in morphology in same trophic guild irrespective of taxonomic proximity. Nandi and Saikia (2015) found two morphological groups of indigenous small fresh water fish species feed depending on the prey size. Gomes *et al.* (2003) found resource partitioning based on prey size in the Anil estuary in Maranhao, Brazil. But conclusions often counteracted others. Motta (1988) concluded that morphology is not a good indicator of trophic guild, foraging behavior can also affect trophic ecology (Soares *et al.*, 2013). To understand better the spatial and trophic segregation of species, relationship between morphometry, habitat and resource utilization have to be investigated in detail.

PROBLEM:

Two questions are prominent from the above discussion-

1) Does habitat regulates morphometry of fish species on different gradients irrespective of their taxonomy? What are these major gradients?
2) How morphometric variations among same or closely related fish species influence resource utilization?

REVIEW OF LITERATURE:

Comparison of anatomical features of organisms has been the key interest for biologists till twentieth century. The purpose was then taxonomic classification and enhancement of concept about biodiversity. '*Quantification revolution'* (Bookstein, 1998) occurred during early twentieth century with the development of correlation coefficient (Pearson, 1895), analysis of variance (Fisher, 1935), principal component analysis (Pearson, 1901; Hotelling, 1933) (Adams *et al*., 2004). In modern ecology, Hubbs was one of the first who wrote a chapter on the morphological correlates of hydrology in fishes (Hubbs, 1941) in 'The relation of hydrological conditions to speciation in fishes', explaining relationship between morphology and ecology (Franssen *et al*., 2014). In mid-twentieth century, values of morphological shape were combined with statistical

analyses to describe patterns of shape variation within and among groups, 'Morphometrics' developed.

In 1960's and 1970's, a new discipline arises, 'ecomorphology' (Franssen *et al*., 2014). Usually linear distance, counts, ratios, angles were measured. Statistical analyses included principal component analysis, factor analysis, canonical variates analysis, discriminant function analysis. Many studies investigated allometry (Adams *et al*., 2004). Lot of effort suggested for removing size or to standardize for it (Sundberg, 1989). But the problems associated with it were shortcomings in case of graphical representations, location of distance measurements was not included in the data, so some aspects of shape were lost (Adams *et al*., 2013). These uncertainties lead to a process called 'Geometric Morphometrics'. This process involves statistical analysis of shape variation and its co-variation with other variables (Adams *et al*., 2013). First described by Strauss and Bookstain (1982) (Franssen *et al.,* 2014). It included methods for both outline and landmark data. Kendall and others developed statistical theory for shape analysis (Adams *et al*., 2004). Bookstein (1996) referred to this as '*Morphometric Synthesis'*.

In vertebrates, the impact of diet, head shape and behavior has been studied in snakes by Fabre *et al.* (2016) by geometric morphometrics. They found snakes with different diets differ in overall shape of the head and mandible. The snakes which are dietary generalists and prey upon large and bulky creatures have wider and taller heads. Fishes have been the largest group for extensive morphometrics study in animals. In teleost fishes, the jaw system have shown that different phenotypes can converge on the same area of functional space, resulting in many-to-one mapping of morphology on function (Wainwright *et al.,* 2004; Alfaro, Bolnick and Wainwright, 2005). If selection on function is strong and the morphological solutions are limited, then convergence is expected to occur (Herrel *et al*., 2008).Trapani (2003) used geometric morphometrics to trophically polymorphic cichlid *Cichlasoma minckleyi* to asses and compare size, shape and allometric patterns within and between dental morphs. According to him, dental morphs exhibit variable patterns of body form. Soares *et al*. (2013) investigated the ecomorphological patterns of the fishes inhabiting in the tide pools of the Amazonian coastal zone, Brazil. Rodrigues *et al.* (2015) studied fish community of Mangueira lake located along Atlantic coast-line in southern Brazil. They concluded that the longitudinal gradient was related with water flow and wind pattern which further affect trophic cascade. Burress *et al.* (2016) studied ecological clustering of minnows of New river, U.S.A. according to morphological, dietary and isotopic data. They found most variations associated with habitat and trophic specializations were caudal peduncle morphology and orientation of mouth. In India, Nandi and Saikia (2015) investigated role of morphometry in feeding success of small freshwater fishes like *Amblypharyngodon mola, Puntitus ticto, Esomus danricus*. Gradient models used to organize species by their traits for e.g. r versus K continuum. Winemiller's model can predict association between fish distributions and invasion success in relation to hydrologic alterations (Frimpong and Angermeier, 2010)

typical ecomorphological characteristics which are evolutionarily distinguishable from its neighbouring ones. On this context, following gaps are prominent on fish ecomorphology-

(a) No strategic and habitat wise ecomorphological data are available for majority or all of the freshwater fish species. Ecomorphological interpretations are totally lacking in case of Indigenous fish species (Nandi and Saikia, 2015).

(b) Although important, the response of resource utilization of the freshwater fish morphology to the variations in the freshwater aquatic habitat has not been attempted at all.

(c) The information on the ecomorphology of freshwater fishes on the line of adaptation and evolution with statistical modelling is not available.

OBJECTIVES:

1) To characterize morphometric variations of some indigenous freshwater fish from West Bengal.
2) To investigate possible habitat- morphometric correlation in response to several physico-chemical gradients.
3) To analyze pattern of resource (diet) utilization by different fish groups corresponding to their congruent morphological features.
4) Suitable morphometric-environmental model to be constructed.

METHODOLOGY

1. Site selection: Different geographic regions throughout West Bengal will be selected for survey.

2. Fish sample collection: Fishes of different species, particularly the indigenous species will be collected from the selected site.

3. Morphometric analysis: different morphometric measurements of fish body will be recorded such as area of the anal fin, area of the caudal fin, area of the pectoral fin, area of the pelvic fin, breadth of the caudal peduncle, breadth of the mouth, head breadth, head height, head length, height of the caudal fin, height of the caudal peduncle, height of the dorsal fin, height of the eye, height of the midline, height of the mouth, length of the anal fin, length of the caudal peduncle, length of closed snout, length of the digestive tract, length of open mouth, length of the pectoral fin, length of the pelvic fin, maximum body breadth, maximum body height, standard length. Then will be compared with ecomorphological indices.

4. Water quality analysis: ecological parameters like Dissolved Oxygen, pH, temperature, turbidity, nutrient, chlorophyll, salinity will be recorded using standardized methods/tools.

5. **Gut content analysis:** The gut content will be collected following standardized procedure and analyzed under inverted microscope. Percentage of stomach content will be studied following Palomares et al (1997). Dietary breadth and overlap will be measured following standard indices of Hulbut (1978), Levins' (1968), Saikia (2012), Schoener's index (1970) and Smith (1982). Ivlev's (1961) electivity index will be used to measure the feeding strategy or feeding performance on resources by the fish. This will be analyzed further according to Haroon and Pittman (1999).

6. Modeling: Appropriate model will be done using relevant software.

7. Statistical analysis: Statistical analysis will be performed using standard software (SPSS 16.0). Variation among means will be compared by ANOVA following Tukey's test.

TENTATIVE YEAR WISE PLAN

First year	Site selection, physico-chemical parameters recoding, Fish sample collection and identification
Second year	Sample collection, physico-chemical parameters recoding, morphometric data collection and analysis, gut content and resource data collection
Third year	Morphometric data collection and analysis, gut content and resource data collection and analysis, habitat characterization and statistical analysis
Fourth year	Statistical analysis for morphometry-habitat, modeling on collected data
Fifth year	Construction of Models and validation, Data compilation and thesis writing

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